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THE LOW TURBULENCE WIND TUNNEL OF THE UNIVERSITY OF MARYLAND

by

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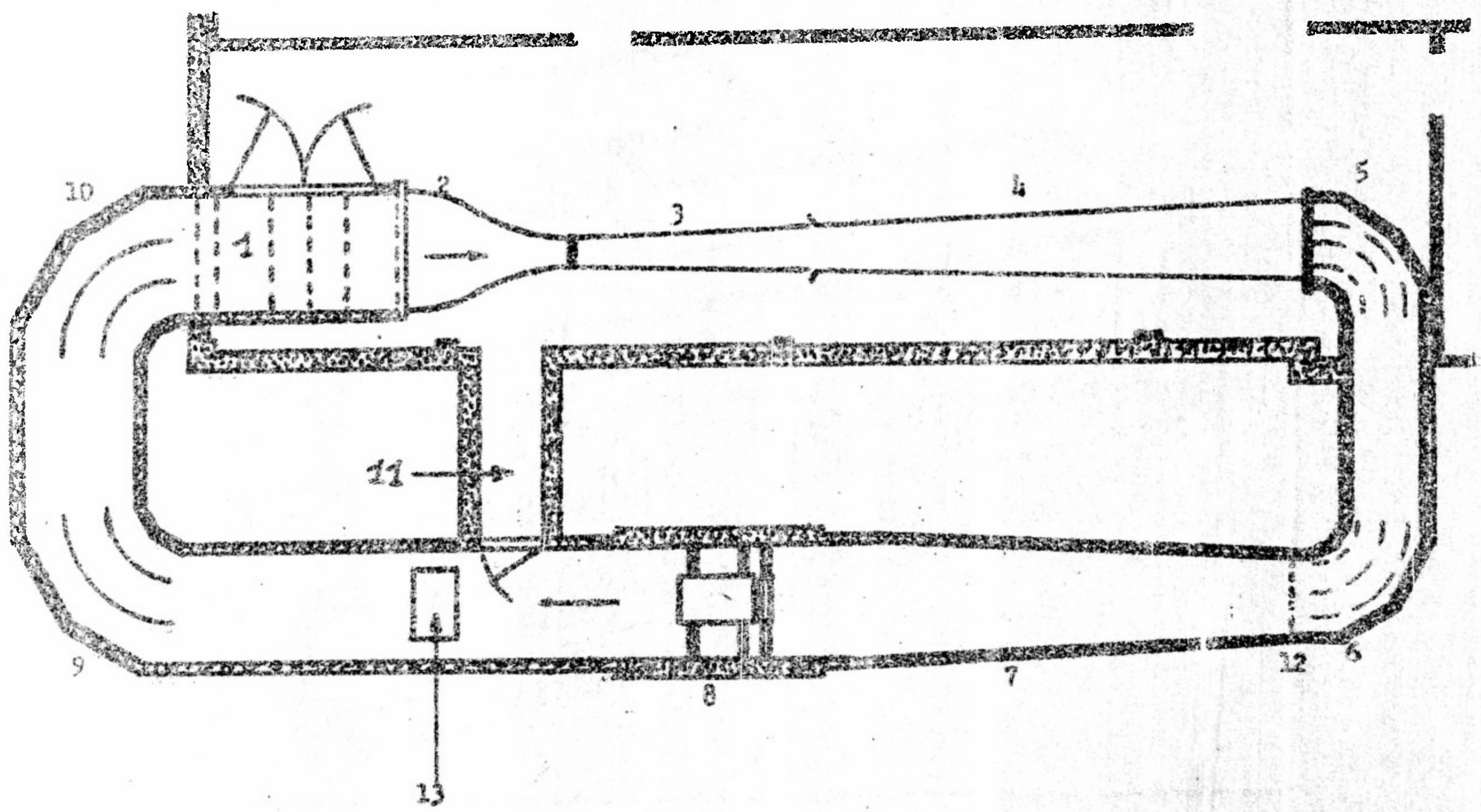
When the new Physics Building of the University of Maryland was planned, the idea of including a small wind tunnel with the building was promoted and with the sponsorship of the United States Air Force the project was realized. In November 1953, the tunnel was completed and tests demonstrated its ability to operate with low turbulence.

This is a description of the tunnel and a manual of its operation.

Description.

The tunnel is located below ground level, partly within the Physics Building and partly outside. Figure 1 indicates the general outlook and Figure 2 sketches the return channel, located entirely underground, outside the building.

On Figure 1 we indicated the settling chamber 1, spanned by 5 to 8 screens, where the turbulence of the incoming flow is reduced before it enters the contraction cone 2. The test section 3 follows and, after a gap, the flow enters the first diffuser 4. The corners 5 and 6 are provided with metallic vanes and lead to the second diffuser 7. The motor and propeller unit is located at 8 and, after two large turns equipped with wooden vanes 9 and 10, the flow returns to the settling chamber. Access to the tunnel is possible through the passage 11, the doors of the settling chamber 1, a panel hole at the end of diffuser 4, the lateral doors of the test section 3 and the gap at the beginning of diffuser 4. The distance between the corners 6 and 9 is about 80'. The contraction cone 2, the test section 3 and the



THE WIND TUNNEL
Fig. 1

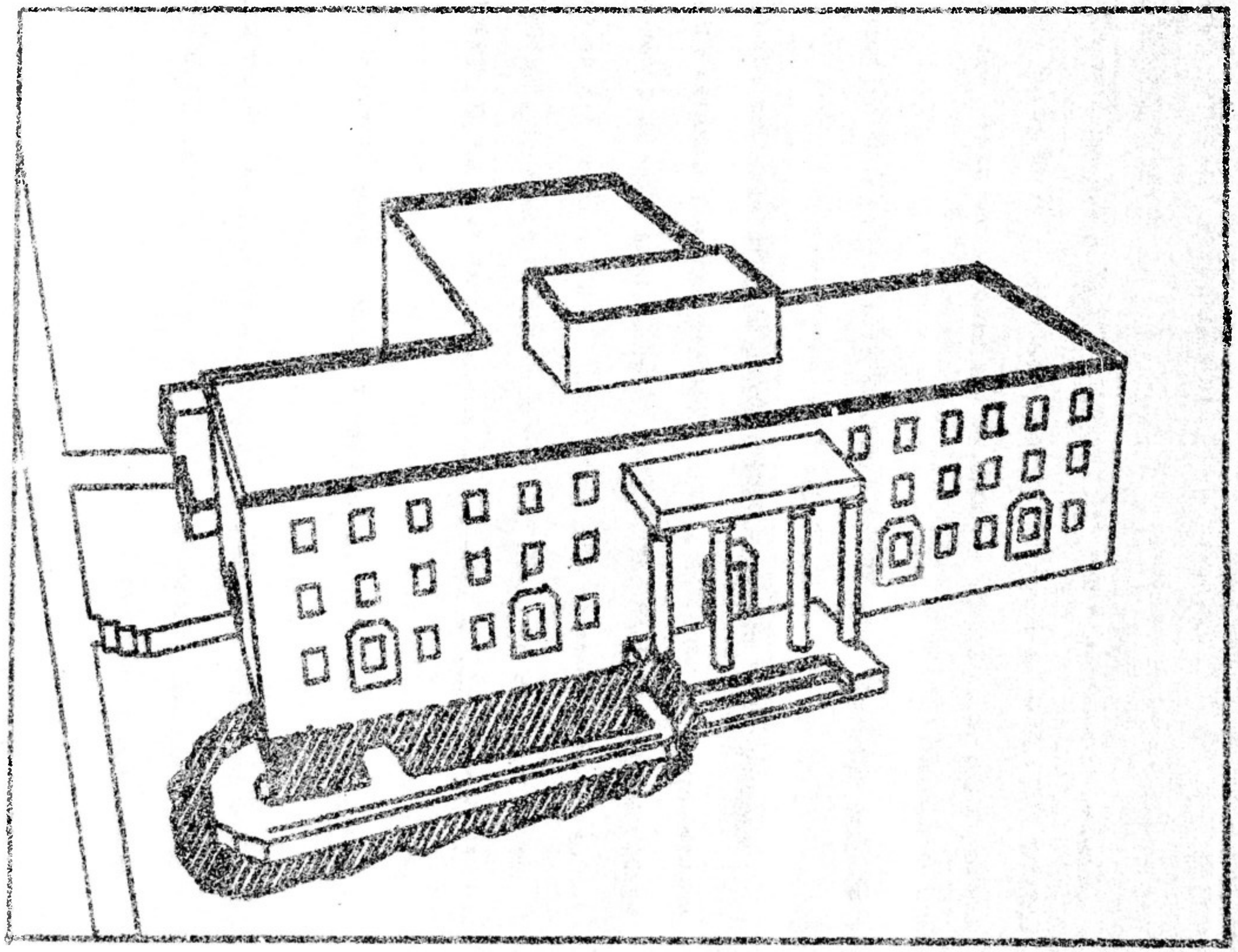


Fig. 2 PHYSICS BUILDING AND WIND TUNNEL.

diffuser 4 are made out of wood and the rest of the tunnel is made of reinforced concrete. The cross section is orthogonal except for the motor-propeller section, where it is circular.

<u>The settling chamber.</u>

The section has a length of about 12' and the distance between parallel walls is 78". A double door permits one to enter the chamber, inspect and clean the screens and eventually install measuring probes. This heavy steel door carries an armature such that the octagonal cross section is complete when the door is closed. When the door is open, the screens can easily be slid outside.

At the entrance of this chamber there are two heavy screens (phosphor bronze, 4 meshes per inch, with a solidity of 0.462 defined as the ratio of open area to total area). The distance between these screens is 21" or 84 meshes. These screens are fixed by bolts to steel pieces, imbedded in the concrete and later on referred to as "T" slots. These T slots (see fig. 3) are used in many places of the tunnel to anchor accessories to the concrete wall. These heavy screens cannot be removed without demounting the vanes of corner 10. The lighter screens have 20 meshes per inch and a solidity of 0.436. They are mounted on flat iron octagonal frames and the frame is bolted to the T slots provided on 5 sides of the chamber. The screen can be stretched, once in place, since it is held between two steel frames as indicated on fig. 4. Between the settling chamber and the contraction cone, a 4" wide wooden ring is provided. That ring permits a close fit between the steel ring terminating the concrete work and the prefabricated contraction cone; and it is bolted to the steel ring.

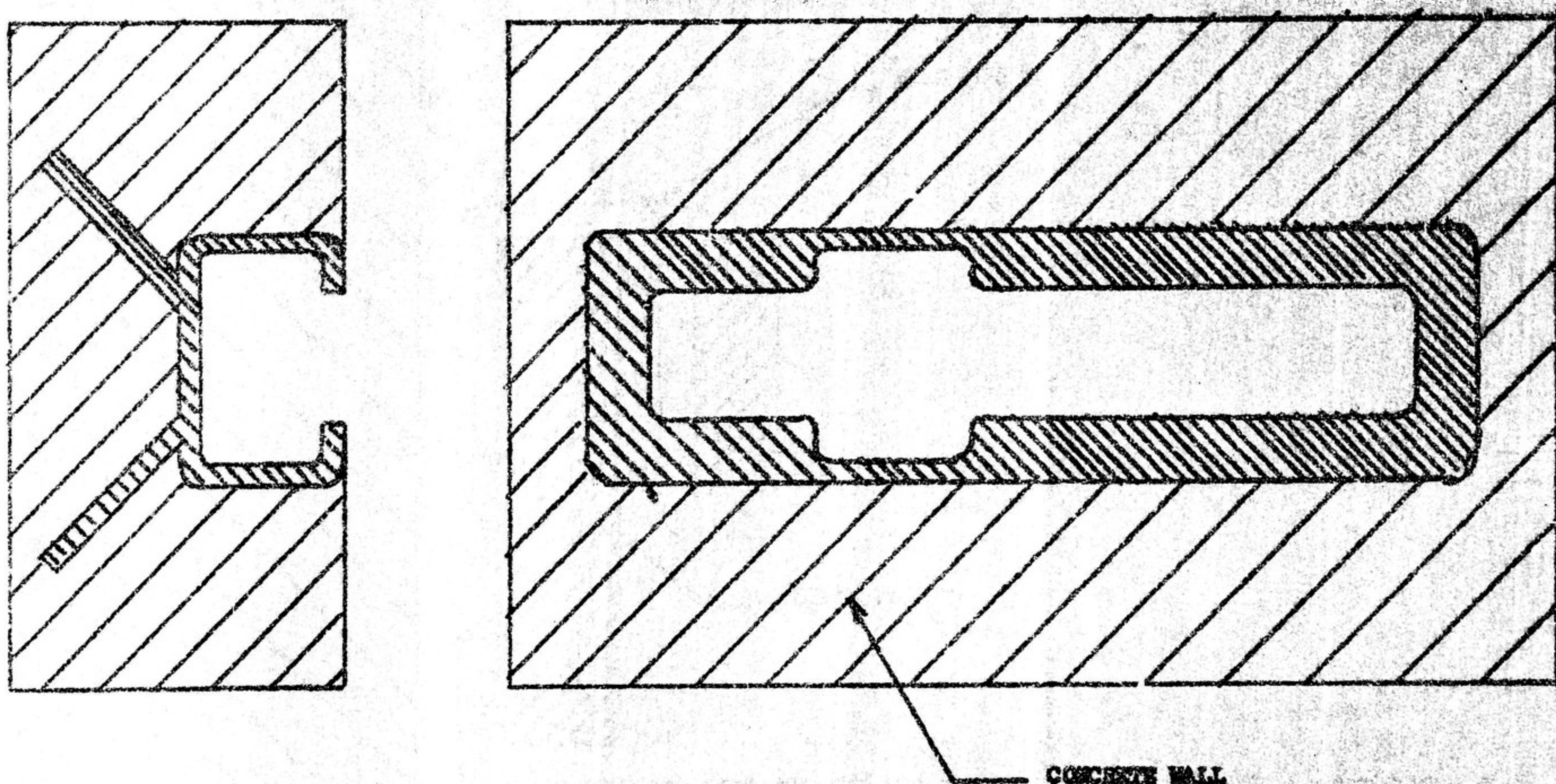


Fig. 3 "T" SLOTS

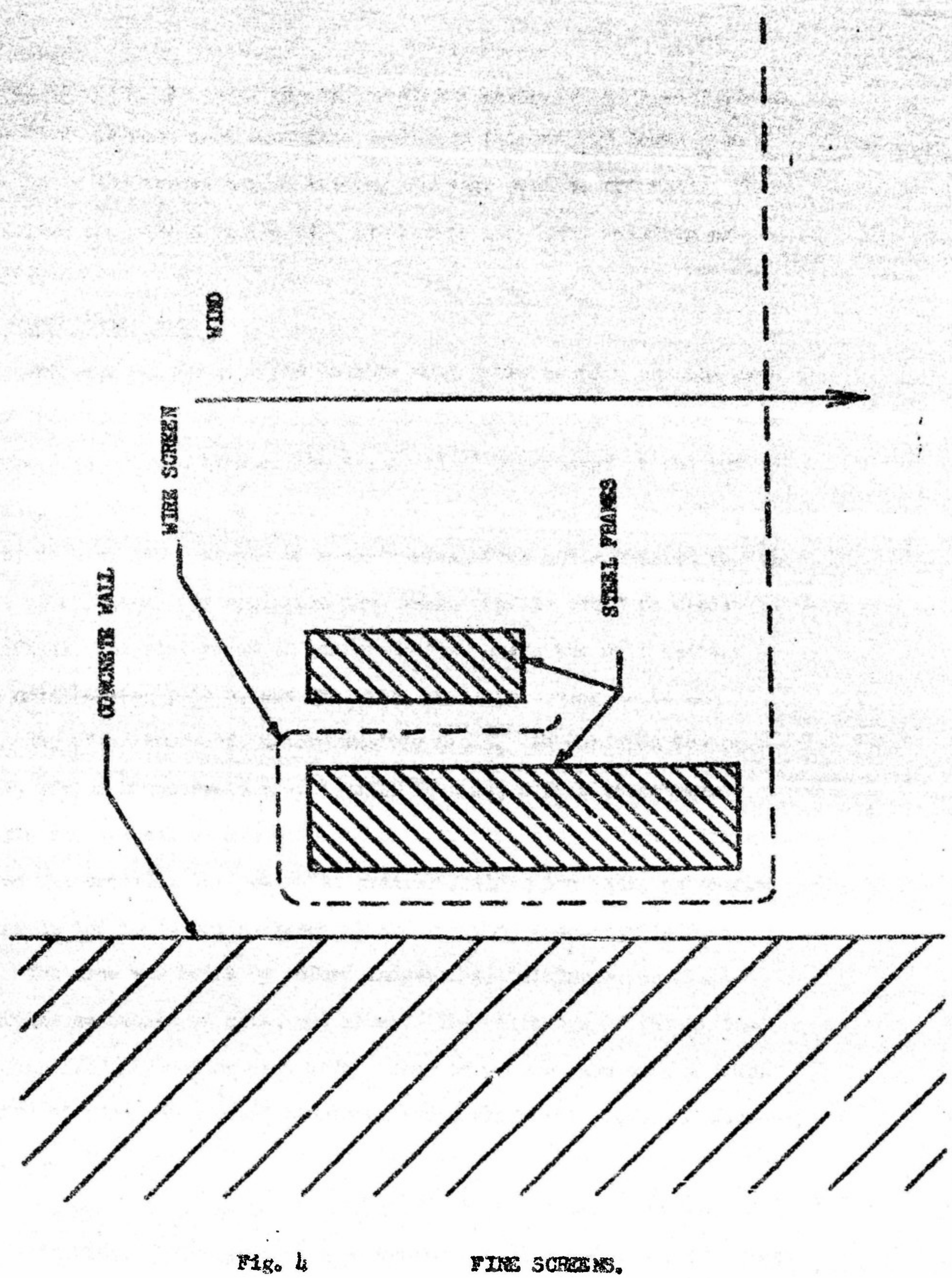


Fig. 4 FINE SCREENS.

The wooden ring can carry one or two fine screens (we used only one). These last screens were therefore installed without any frame protruding in the tunnel and disturbing the flow next to the wall. We installed one screen on the ring (20 meshes per inch, solidity of 0.436).

The contraction cone.

The contraction cone has an octagonal cross section and the profile indicated on Fig. 5. This profile was selected after some tests in the electrolytic tank of the Aeronautical Department of the University of Maryland. We tilted the tank (dimensions of about 6 by 9 feet) to have the analogue of a cylindrical flow and simulated the wall of the tunnel by a plastic dam, whose profile could be easily modified. The difference of the potential, along the wall between two neighbouring points, was measured, as it is analogous to the velocity of an inviscid, incompressible fluid. We selected the profile, giving a contraction of 1 to 16 in area, with a reasonable length and a small overshooting of the wall velocity. Fig. 6 indicates the profile, the potential gradient, along the wall, as determined in the tank, and a sketch of the inclined electrolytic tank.

The cone was built by McCord Industries, Baltimore, in eight sections assembled at site, and glued. The walls are 3" thick, including 1/8" plywood on each side. They have been made with a great number of pine ribs, glued together, and a system of rings and legs completes the unit.

The cone can be moved, by means of a jack, in the direction of the mean flow. This gives easy access to the ring and the last screen. The contraction cone is fixed by 7 bolts to the steel ring terminating

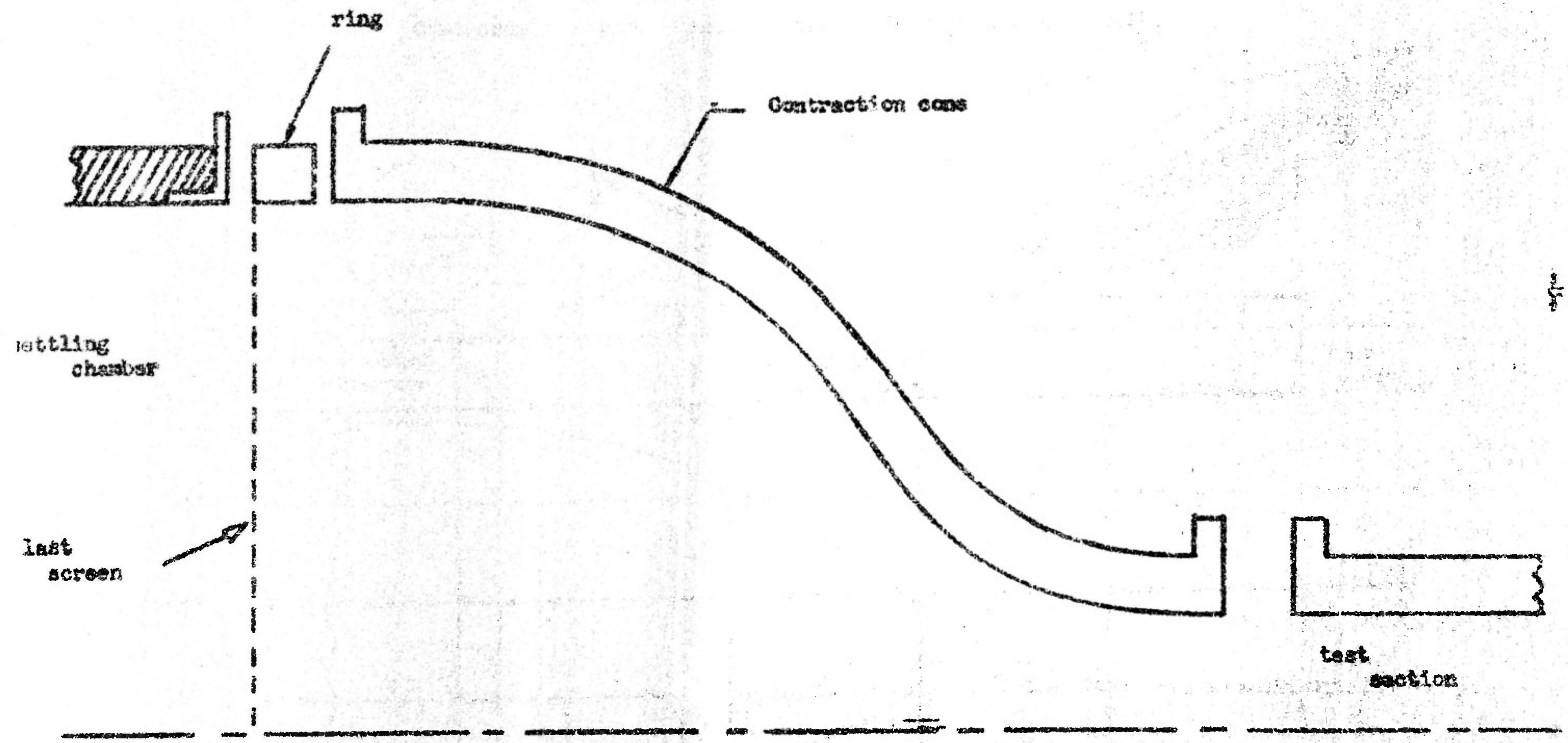


Fig. 5 CONTRACTION CONE

Contraction cone, shape and velocity at the wall.

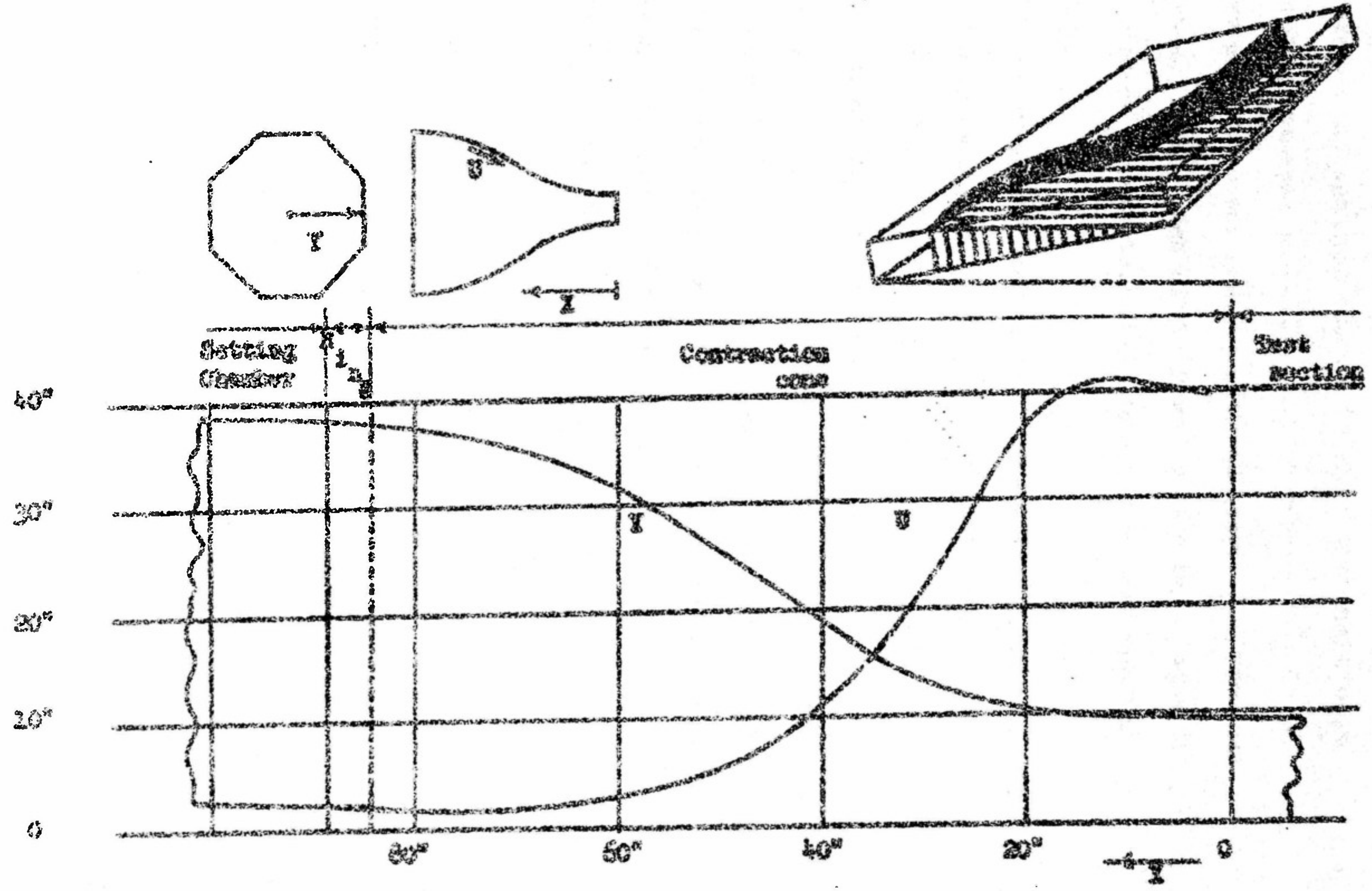


Fig. 5

the settling chamber and one must not try to slide the cone without previously checking that all bolts have been removed.

The narrow end of the contraction cone and the test section can be bolted together, or a screen can be inserted in between, when it is desired to produce a known turbulent field in the test section.

The test section.

The distance between parallel walls, at the entrance, is 19 3/4"; and the walls diverge with a 1° angle, wall to wall, giving at the end a wall distance of 23". The length of the test section is 191". Without any grid producing turbulence at the entry of the test section, this divergence produces a drop of velocity along the test section inversely proportional to the cross section. With a grid producing turbulence, the boundary layers against the walls of the test section are more important and a divergence of the walls is necessary to maintain a uniform mean flow. However, the angle of 1° proved to be too large, and a smaller divergence would be more convenient.

The test section is mounted on a steel support and rests on three legs. These legs are bolted to a large concrete slab, provided as a special precaution against vibrations. This slab of approximately 6' by 12' has a thickness of 1', and is on the same level as the floor. It rests on a dry sand bed, filling a water-proofed cavity in the floor of the room. The sand bed is approximately 1.5' deep. The gap between the slab and the floor is filled with pre-moulded mastic. The system is analog to a low pass filter, with the slab acting as a mass and the sand as a spring, and has been provided as a precaution against vibrations transmitted from the floor to the

test section or the stands holding the measuring probes.

The test section can slide on the three legs, once the bolts securing it to the contraction cone have been removed. For this purpose it is convenient to slide two cylinders under the steel frame. This permits one to easily change the grid producing turbulence, at the entry of the test section. The test section was made in two halves, with 1/2" plywood, glued along the eight corners and assembled in four steel frames. Then the upper sides were partly removed and replaced by windows. Each half has a window of about 80" by 10", allowing light to enter the test section from above. The side panels were also replaced by two doors and reinforced by special wood pieces. Fixed with piano hinges, these doors of about 80" by 10" provide easy access to the test section. Four holes, with brass collar and plug permit the insertion of a Pitot tube at four selected points of the test section. Six plastic tubes make it possible to connect the Pitot tubes with manometers, conveniently located. The inside of the test section has been polished and the glass windows provide a very smooth wall.

The gap.

Between the end of the test section and the entrance of the first diffuser a gap of about 6" permits one to bring coaxial hot-wire cables into the tunnel, to fix the static pressure at this point of the air circuit and to move the test section back by a few inches, when it is desired to change the turbulence-producing grid or the last screen, on the 6' ring, before the contraction cone.

With the gap unobstructed, the static pressure at this point in the tunnel circuit is equal to the pressure in the room, referred to in what follows as zero pressure. This puts all parts of the tunnel, except the test section, under positive static pressure and the various leakages create a draft of air entering the tunnel at the gap. This draft increases the boundary layer at the beginning of the diffuser, and must be reduced as much as possible for efficient operation.

The gap can be tightly closed and four panels can be opened at the end of the first diffuser. Then the diffuser operates under more favorable conditions, but the access to the test section is complicated. We tried to install the gap sight blades and to suck the boundary layer formed in the test section out of the tunnel, with zero pressure at the end of the first diffuser. However, this requires a large compressor, adding undesirable noise and vibrations and brings only moderate improvements.

Finally we installed a streamlined collar at the entrance of the diffuser, and thereby slightly improved the flow in the diffuser.

The first diffuser.

This diffuser has a wall-to-wall angle of 5° and consists of seven sections, made of 1/2" plywood, glued at the corners and assembled in 1½ steel frames. These sections are assembled two by two, except the last one, and mounted on angle iron legs. The floor is provided with T slots and the sections are anchored to these slots. Rubber rings are inserted between the sections and the inside has been reasonably polished. A screen of 20 meshes per inch (solidity

of 0.436), installed near the end of the diffuser, has improved the stability of the flow.

Four panels of about 20" by 20" can be removed at the end of the diffuser. It is possible to stop the inflow at the gap by forcing air into the tunnel through one of these panels, in order to balance the leakage. But this again would require a compressor of some power (1 - 2 H.P.) and would add noise and vibrations.

A cat-walk permits one to cross the diffuser. The first section of the diffuser, immediately behind the test section, can easily be removed, if the test section or the contraction cone has to be displaced by a large amount.

Between the last section and the steel ring marking the entrance to the concrete return channel, we found it necessary to insert a wooden ring. This ring was custom made, since the steel ring does not exactly lie in a plane perpendicular to the axis of the tunnel, and since the end of the diffuser also has some imperfections. This wooden ring is bolted to the steel ring. The wall-to-wall distance at the end of the diffuser is 52".

The small corners.

The flow now enters the concrete return channel, and passes first through a succession of corners. On Figure 1 we indicated the dimensions and the positions of 30 steel vanes, guiding the flow. Those vanes are curved and welded to pentagonal steel plates. The pentagonal plates are provided with slots and are anchored against the walls of the tunnel to various T slots. The flow turns by a total of 180° without net change in the cross section and we could

not detect any appreciable pressure drop. A man can crawl between the vanes, and they have been assembled starting from the upstream vanes and moving back towards the propeller.

A safety screen is provided after the last vanes to stop any object from flying or rolling into the propeller area. The actual screen has 20 meshes per inch and introduces an unnecessary pressure drop. It is advisable to replace it by a screen offering the same protection with less pressure drop.

The second diffuser.

The concrete walls of this diffuser diverge by 5° 40', wall to wall, and, after a length of 22', bring the channel to a wall-to-wall distance of 78". The last 4' provide the transition from the octagonal cross section to the circular cross section. For that purpose the corners have been filled with concrete.

The motor-propeller section.

This section is circular, over a length of 124". The walls are specially heavy (1') to provide a large mass, and the section is connected to the other sections by copper bellows and a layer of about 1" of pre-moulded mastic and tar. This prevents the mechanical vibrations of the motor propeller section from propagating to the other parts of the tunnel. The inside diameter is 78".

Two channel steel frames, ring shaped, are imbedded in the walls, and emerge flush with the surface of the concrete. On these rings, we welded the stand supporting the motor, consisting of steel pipes and channels.

An electric conduit starting from a convenient point in the tunnel room terminates in a plug within the concrete wall of this section.

To lift and install the motor, we welded, at the highest points of the steel rings, two small steel pieces through which one can slide a channel iron, carrying a small hoist. The motor can therefore be lifted and lowered on the floor, in the rear of the stand. This arrangement permits one to take the propeller out, since it will clear the central region of the tunnel. The motor could eventually pass through the access door 11 (fig. 1). The propeller can only be removed through corners 9 and 10 and through the doors of the settling chamber. This requires demounting vanes and screens in this region.

Passage, return and large corners.

After the circular section, a short transition to the octagonal cross section occurs, and the air flows over 25' in straight line. In this area one could take steps to equalize the velocity distribution (installation of a fuselage behind the motor) or stop the induced rotation of the air. We installed in this area two dehumidifiers to keep the air reasonably dry during the humid periods. The water is evacuated through a copper pipe, via the passage.

A set of T slots is provided in this same area. The air could eventually be heated or cooled, and adequate water lines are available in the tunnel room.

A passage connects the tunnel with the tunnel room through a door (26" by 44") opening in the tunnel. This access is necessary to inspect and maintain the motor, measure pressure or velocities, and

drain infiltrations. Under the door, a small channel (15" by 10") closed by a plywood panel makes it possible to bring pipes or wires into the tunnel, without interfering with the door.

The door, when closed, acts on a special switch inserted in the circuit of the motor. When the door is open, the propeller cannot be energized and this provides a guarantee against the risk of starting the propeller and thereby injuring someone working in the tunnel. Since there are no electric outlets in the tunnel for light or appliances (drilling machines, vacuum cleaners, etc.), the electric extension cables used for this purpose will prevent closing the door and starting the propeller. When the walls of the tunnel are wet, one must also be aware of the danger of electrocution by currents flowing from any electric appliance (lamp, tool, etc.) to the ground through the body.

Precautions such as lower voltages, grounded appliances, rubber shoes, etc., should always be considered.

The large corners turn the flow by 180°, and plywood vanes, 3/4" thick, vertically mounted on angle iron rails, fixed to T slots, prevent the formation of large vortices.

Without the vanes, large vortices build up in the corner 9, with vertical axis, and at irregular intervals they are washed away and appear as large turbulent bursts in the test section (with no screens in the settling chamber). An observer standing in corner 9 could very well notice this process. Without vanes, the velocity distribution in the settling chamber is also highly asymmetric and fluctuating.

With the two large screens and the vanes the flow becomes very quiet and uniform. To test the efficiency of the system of vanes, heavy screens, and four fine screens, we set a hot wire anemometer in the test section, and operated the tunnel with someone standing in front of the vanes (corner9, fig. 1), and obstructing the flow with a large panel (about 3' by 4'). No difference was noticeable, whether the panel obstructed the flow or not, and a burst of turbulence followed each change in the position of the panel. The turbulence was of the order of 2 10^{-4} with a velocity of about 10 m/sec.

The propeller.

The actually installed propeller was not in any sense the result of a special design. We felt that practically any propeller would permit us to operate the tunnel, determine the efficiency of the tunnel and obtain the necessary information to proceed to the next step: the design of a better propeller. The actual propeller was bought from Robinson Ventilating Company, whose production line includes fan wheels for ventilation over wide pressure ranges. The six steel blades are welded to a hub. The diameter of the blade is 76", leaving a clearance of 1" to the wall of the tunnel. The chord varies from about 13" at the hub to 8" at the tip. The diameter of the hub is 22". The propeller is designed to operate with larger mass flows and smaller pressure difference than we have in the wind tunnel. In other words, we are operating with a slightly stalled propeller. The maximum speed is 800 R.P.M., and the wheel has been dynamically tested and balanced by the manufacturer. We do not exceed 700 R.P.M.

The electric D.C. motor and motor generator set.

The electric D.C. motor is rated 25 H.P., 230 volts D.C. It operates from the power supplied by a motor generator set, with an adjustable speed. The motor has a top speed of 2000 R.P.M. and drives a gear box, with a reducing factor of 2.73. The output shaft of this gear box drives directly the propeller. In this way the propeller can operate between 13 and 700 R.P.M. and the motor has the required power without having a diameter larger that 22". (A low speed D.C. motor with the same power and without gear would obstruct the flow considerably). The unit was purchased from Westinghouse and this company could eventually supply another set of gears, permitting one to operate the propeller in a different speed range.

Actually, with 700 R.P.M. the tips of the blades have a speed of 60 m/sec, corresponding to a Mach number of 0.2. The motor has another output shaft, turning at the rotor's speed, and located downstream. This shaft revolves in the same direction as the propeller, but could be used, through a suitable gear, to drive a contra-rotating propeller. Actually, it carries a dented wheel, used as a tachometer. The wheel modulates the reluctance of a small magnetic circuit and a coil picks up a small induced e.m.f. The coil is connected to two terminals on the control panel, and the speed can be measured with a cathode ray oscilloscope. The gear box must be properly filled with oil (16 quarts SAE 40) and an oil level indicator is located on the right side of the gear box. On Fig. 7 we indicated the basic wiring of the electric installation, with the few modifications introduced after

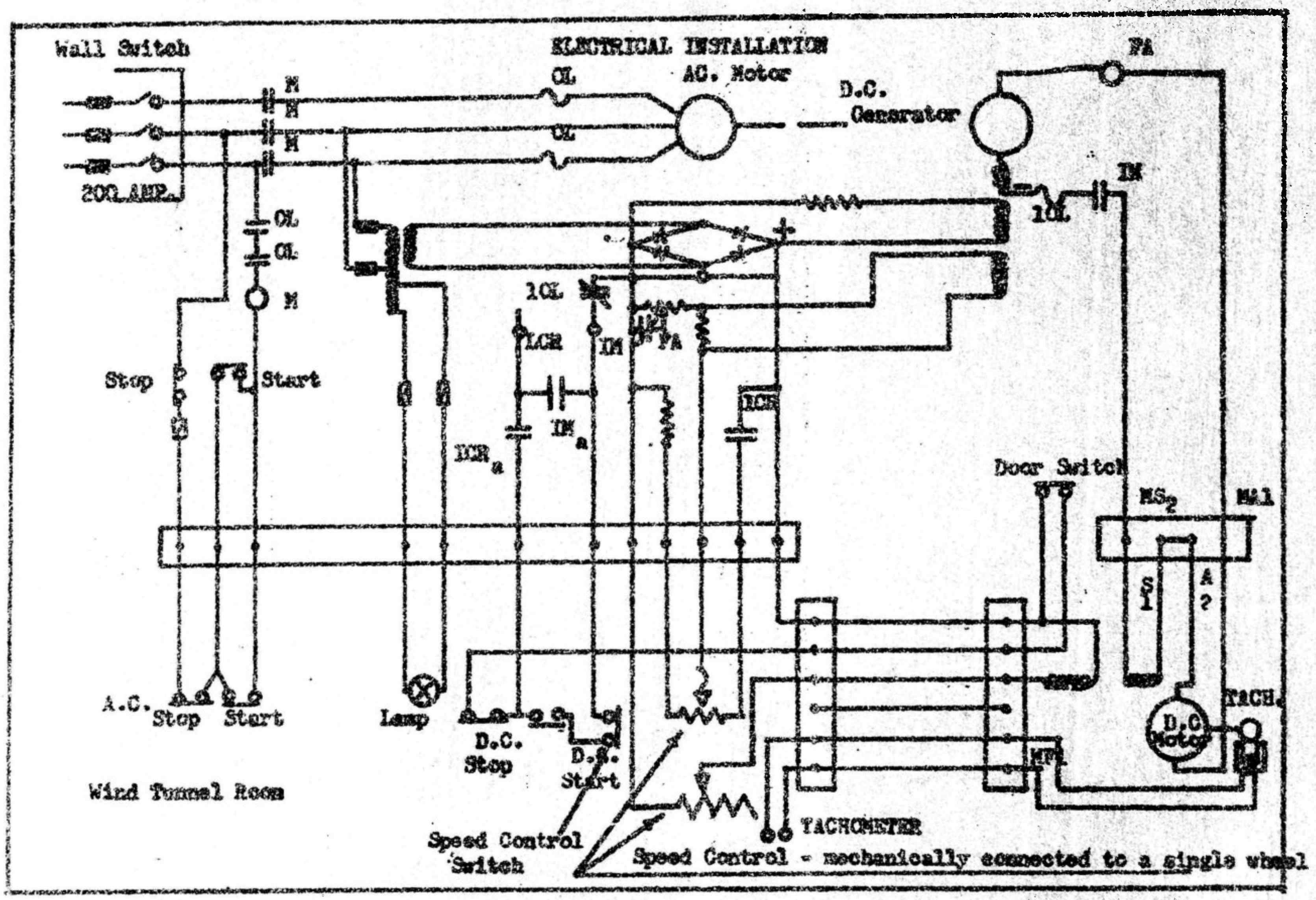


Fig. 7 ELECTRICAL INSTALLATION.

receipt from the manufacturer. The three-phase power line is interrupted by the magnetic switch M. To energize this switch one can use either the Start-Stop buttons on the side of the motor generator set or the push buttons installed in the wind tunnel room. The A.C. motor can therefore be started from two different places as long as the manual switch in the wall panel is not switched off. This point must be kept in mind for obvious safety reasons.

Overheating of the elements OL will open the magnetic switch M and stop the machine.

The A.C. power is tapped to energize a transformer. The primary is fused and can be switched differently to change the operating A.C. voltage. We use part of the primary to deliver in the wind tunnel room a signal of 110 volts A.C. This signal lights a red lamp when the magnetic switch M is closed, and could be used to energize an electronic tachometer.

We measured through one of the three power leads a current of 22 amp when the generator was not loaded. The starting current jumps from zero to a peak of 600 amp, then remains at about 350 amp for 2 seconds. Under load the current does not exceed 150 amp. The actual fuses are rated 200 amp. The secondary winding of the transformer drives a rectifier, and the D.C. e.m.f. is used for excitation of the D.C. generator and motor. To start the D.C. motor one must first set the speed control wheel on the lower speed position. This protects the propeller from large starting torques. In this position the Speed Control Switch (see Fig. 7) is closed, and pressing the D.C. Start button starts the motor.

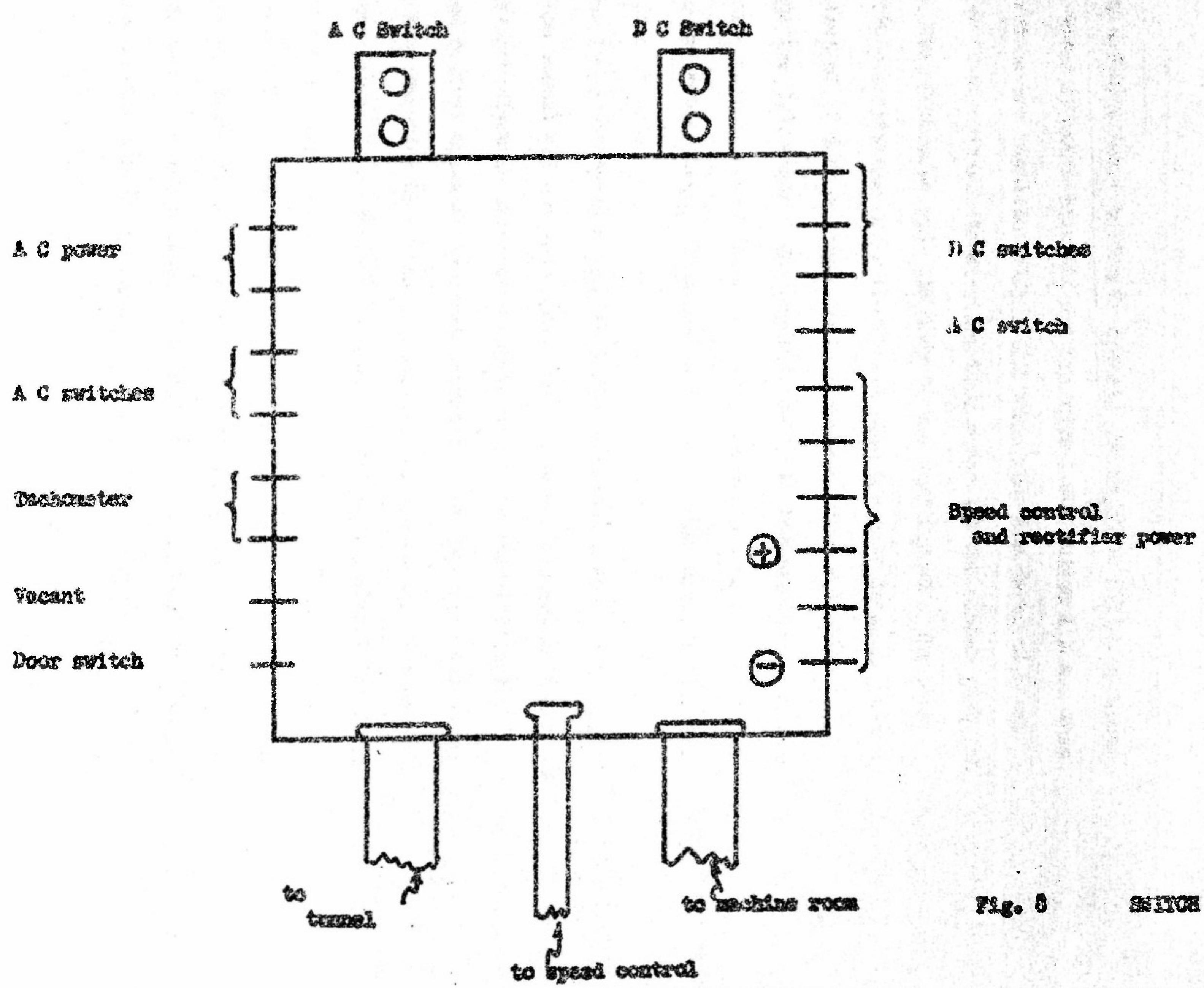


Fig. 8 SWITCH BOX

When the D.C. Start button is closed, the magnetic switch M closes the motor armature circuit, and the auxilliary switch 1 M a. This energizes the magnetic relay 1 C R whose function is to maintain relay 1M energized. To stop the D.C. motor one can either push the D.C. Stop button or open the door to the wind tunnel. The Door Switch prevents operating the tunnel when the door is open. Overheating of 10 L by a large armature current opens switch 10 L and stops the D.C. motor. The magnetic relay FA reduces the excitation of the generator when either the armature current or the rectifier tension is too large. This device operates under accelerating conditions or under maximum aerodynamic load and the relay FA flutters. Under large aerodynamic load this device brings a drop in the speed of the tunnel and unstable operation. A more efficient propeller or a revised electric arrangement would eliminate this difficulty. Speed control operates by first increasing the generator exitation and then reducing the motor exitation. The tachometer is connected to two terminals on the switch box. It delivers a signal whose frequency Π is porportional to the angular velocity of the propeller by a factor, 12 x 2.73. The blade frequency is $\Pi/5.46$. Fig. 8 indicates the basic dispositions of the switch box. The cooling of the motor generator set presents some difficulties and one must use at all times the window fan installed in the machine room.

Water infiltrations and condensation.

The return section, outside the building rests on a layer of coarse gravel, over the undisturbed ground. After the reinforced concrete was in place, the pit was filled with cinder and a last

layer of earth. On each side of the concrete work, in the coarse gravel, two draining lines have been provided. The purpose of this drain is to collect the water under the tunnel and to bring it into the main water sink, located in the wind tunnel room and used for the whole Physics Building. An electric pump removes the water from the sink, once it has accumulated in sufficient quantity. Since the water flows easily through cinder or gravel, we expect no hydrostatic pressure. We observed that large pools of water remained for some time on the surface of the ground, above the tunnel, after major precipitations, but they may be only a consequence of the relative impermeability of the top layer of earth. Before the tunnel was painted on the inside, we noticed wet areas and infiltrations. After the paint was applied, leakages occurred only in the narrow corners, at the entrance of the second diffuser. The water apparently seeps through capillary slits and emerges in hollow spots. Attempts to use a cement (Stadry, etc.) failed since the water leaked out elsewhere.

Finally we cut small irrigation grooves in the bottom of the tunnel and let the water accumulate in a small well (2 cubic inches about), located immediately behind the protection screen. In the well are two electrodes and when the water level is high enough, a small electric pump (electric fuel pump for heavy trucks) is switched on by the first electrode. When the well is dried, the second electrode turns the pump off. The water is pumped outside through a copper pipe, terminating in the room, under the last section of the first diffuser. This copper pipe is used as ground connector for the electronic relay driving the pump. This solution is provisory since it is known that such water infiltrations change with time.

When the wall of the tunnel is cold, condensation takes place. Then the dehumidifiers must be turned on, and the tunnel must be closed. When the temperature drops below freezing, the dehumidifiers must either be turned off or protected against frost.

Water and condensation has never interfered with the operation of the tunnel; the problem is a matter of maintenance.

Paint.

The inside walls of the concrete part of the tunnel were sand blasted, and a primer (similar to Sery 700, Gates Engineering Company, Wilmington, Delaware) was used before the final coating was applied. The coating itself was Neoprene, Sery 700, same manufacturer. The minimum thickness is .006 inches, but the paint did not fill all the cavities of the concrete, since some of them are forming small caves. However, no dust is produced by the concrete and the coating is quite resistant to abrasion.

The use of rubber shoes and other similar precautions is strongly recommended.

The neoprene coating had a very marked effect on the accoustical properties of the tunnel. It introduced a very desirable damping and contributes certainly to the quiet operation of the tunnel.

Pressures and energy.

We found that the various static and dynamic pressures always varies as the square of the velocity at the entrance of the test section, even when no screens or large vanes are installed. This means that the efficiency is independent of the speed, except for propeller considerations.

The maximum speed depends upon the number of screens installed and the temperature of the motor generator set. Operation with low turbulence is possible up to 45 meters/sec, or even 50 m/sec. On top of Fig. 9 the indications refer to the operation of the tunnel without large vanes and without any screen. The flow in the settling chamber is unsteady and the turbulence produces large losses in the test section. The energy ratio is about 2.

With the large vanes and the two large screens (4 meshes per inch) the flow is in the settling chamber and the test section losses are reduced. However the inflow at the gap creates some large fluctuations in the diffusor. With five additional screens, as indicated on Fig. 9, [illegible] the efficiency of the diffusor is somewhat improved. The screens introduce additional losses and the energy ratio is 2.2 to 2.3. The flow is now steady at all points. The energy ratio could be improved by installing a better protection screen before the propeller.

With a speed of 40 m/sec at the entrance of the test section, and with an energy ratio of 2.2, the corresponding power is about 5 H.P. We estimate the efficiency of the motor propeller unit at 0.27, and therefore the electric power necessary to maintain this speed becomes 18 H.P.

Larger speeds would therefore require a better propeller, or a system of contra-rotating propellers. A stream lined hub around the motor would also improve the efficiency. Actually, the maximum speed is about 45 m/sec or 90 m.p.h. When a grid is introduced at the entrance of the test section it creates a large pressure drop,

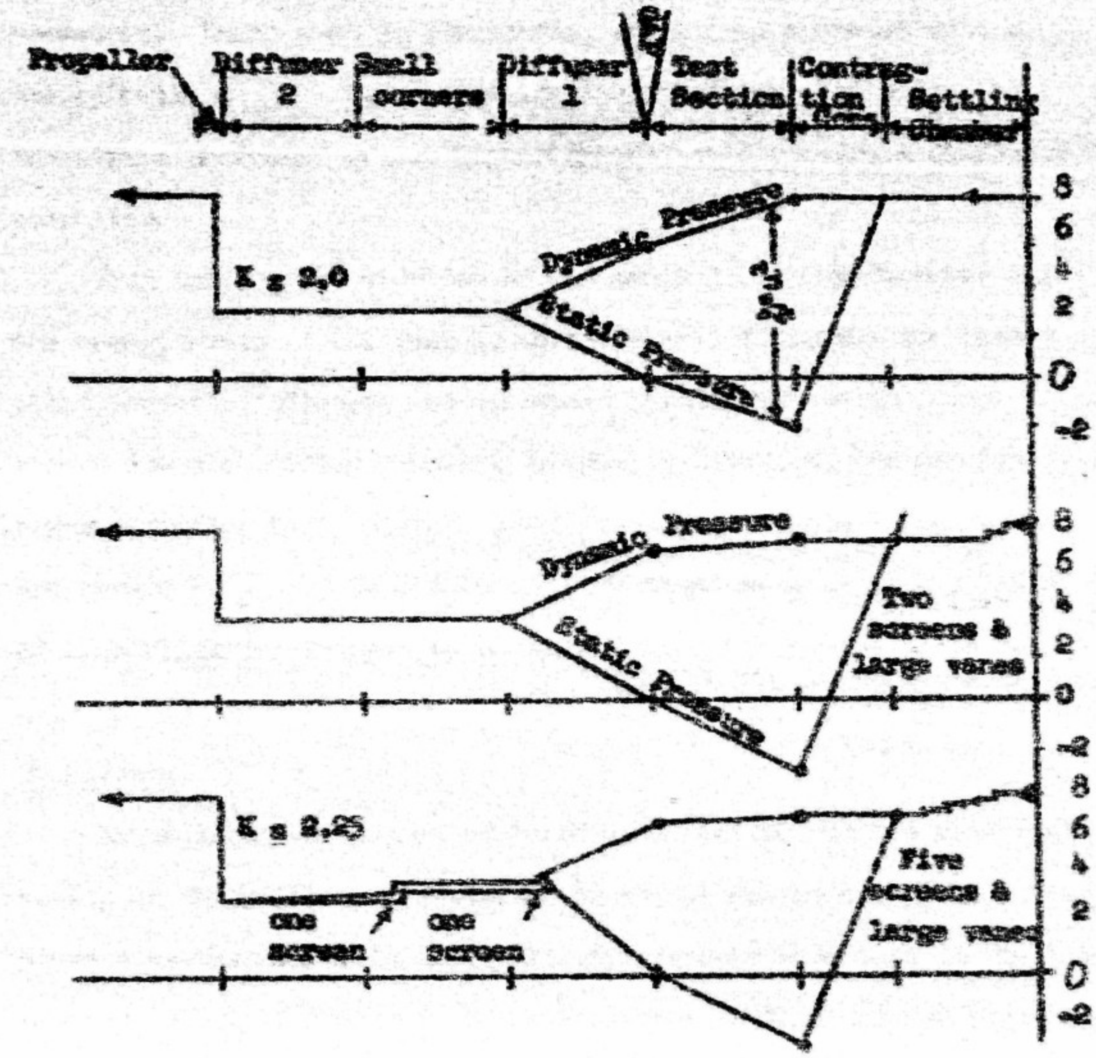


FIG. 9 Pressures in the Wind Tunnel with Various Arrangements

K = Energy Ratio P in CM. of Water

of the order of 2 times the difference between dynamic and static pressures. Under such circumstances, the tunnel operates with an energy ratio of less than 1 and the largest losses are due to the turbulence producing grid. Higher speeds would require a different propeller.

From information supplied by the propeller's manufacturer and the energy ratio of the tunnel, we could draw Fig. 10. The tunnel characteristic indicates the operating conditions and the other curves are plotted for constant R.P.M. Furthermore, the manufacturer indicates that points A B C D correspond to electrical maximum powers of 5, 10, 20 and 40 H.P. A rough estimate of the ratio of electrical power input to aerodynamical power output gives values between 0.3 and 0.27.

Turbulence.

We measured the degree of turbulence, defined as the root mean square of the velocity fluctuation in the direction of the mean flow, divided by the mean velocity. All measurements were made in the test section, about 50 inches from the entrance. With the large vanes and two large screens (4 meshes per inch) we found the values indicated by crosses on Fig. 11. At 10 m/sec the turbulence was about 0.4%. With the addition of one screen, mounted on the large ring just before the contraction the turbulence was reduced by a factor 4. The values are indicated by circles on Fig. 11. After addition of two screens in the settling chamber and two other screens in the diffusors, we observed another reduction by a factor 10 and a turbulence of .02 to .03 percent at high speeds. The points are indicated by dots on Fig. 11.

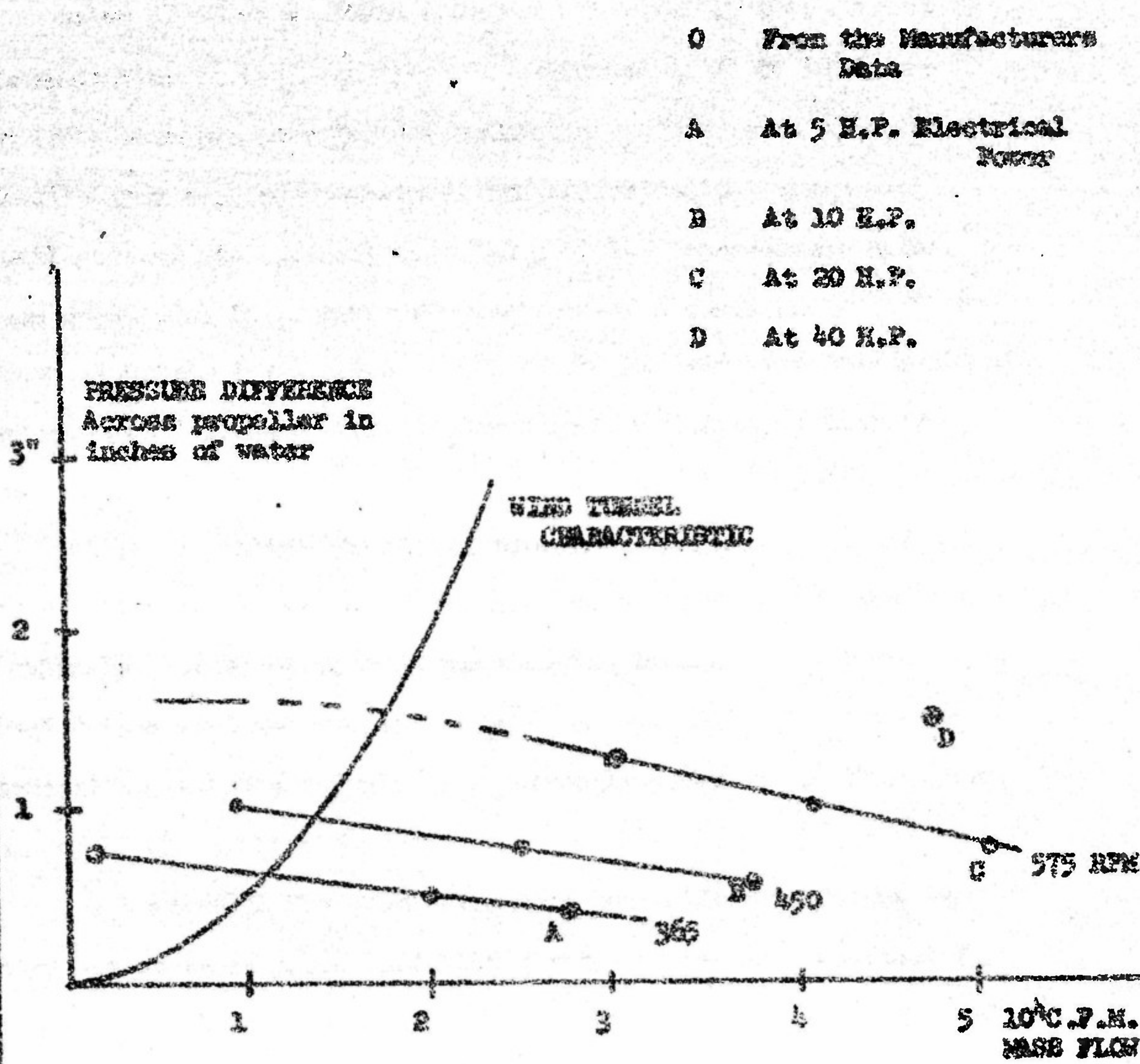


FIGURE 10

PROPELLER CHARACTERISTICS

Below 15 m/sec we found that two hot-wires located on a plane perpendicular to the mean flow but separated by 10 to 15 inches indicate strongly correlated fluctuations. This means that the fluctuations are one-dimensional and correspond to "organ-pipe" oscillations. An apparent turbulence of 10^{-4} corresponds under such conditions to pressure fluctuations of 5 dynes per cm^2, or to sound at speech level. The signal of the hot wire fluctuates slowly and does not indicate a particular superposition of various frequencies.

At higher speeds the signal appears more random, the lateral correlation falls, and the turbulence does not vary with the mean velocity. At 30 m/sec we found that the lateral correlation falls over 2" and that the average "length" of the eddies is about 10", indicating that the turbulence is strongly asymmetric. This effect is due to the contraction cone.

We arrived at the conclusion that accoustical phenomena are dominant up to 15 m/sec. and that turbulence becomes important for higher speeds. The Reynolds' number based on eddies of 30 cm, and velocity fluctuations of 30 m/sec reduced by a factor 10^{-4} is of the order of unity and therefore those large eddies are rather stable. Further reduction of the turbulence or sound fluctuations would require more screens in the settling chamber or some large screen or honeycomb to filter out the large eddies. To reduce accoustical effects, one could perhaps replace the large vanes by similar vanes made out of some sound absorbing material.

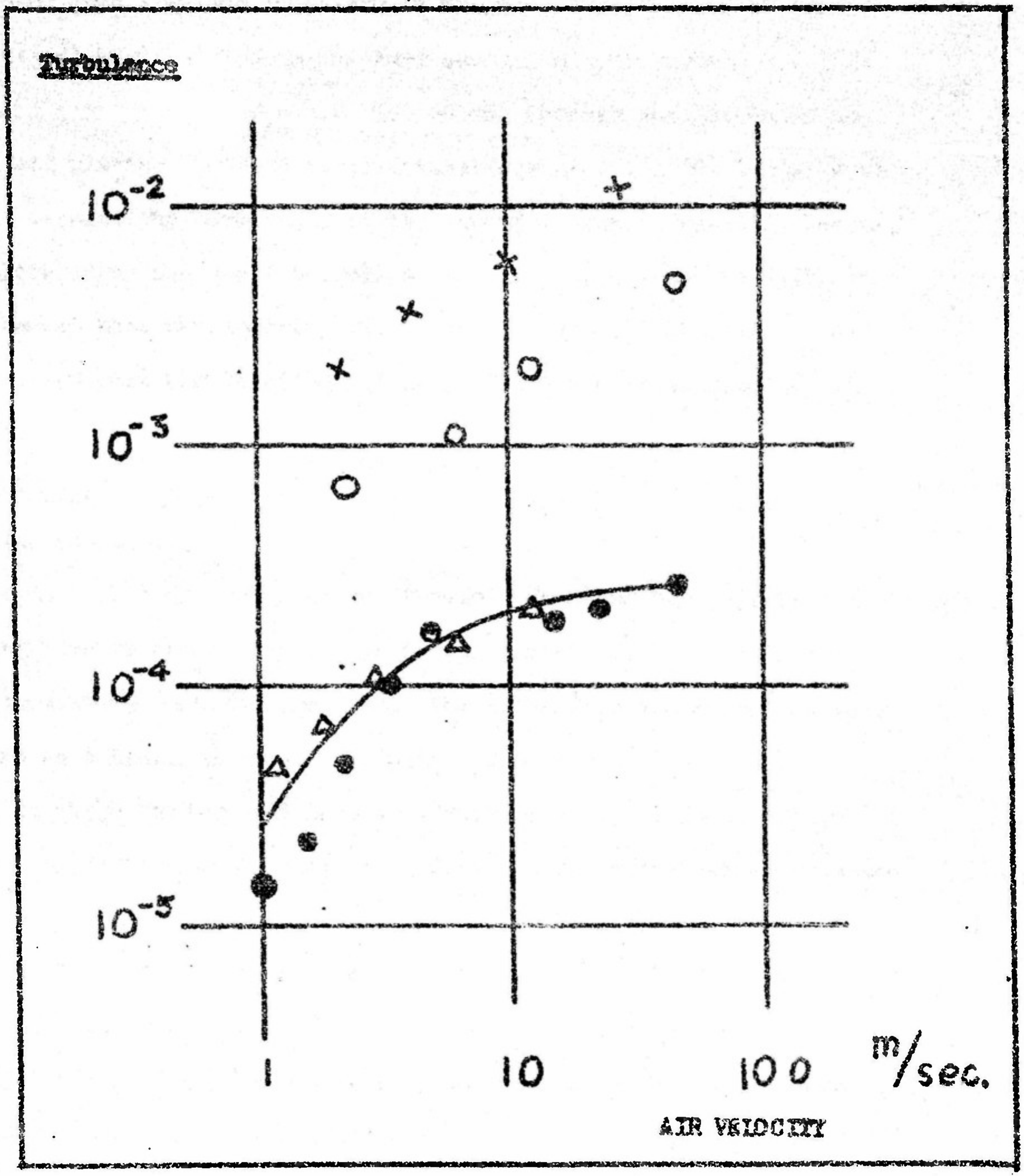


FIG. 11

TURBULENCE IN TEST SECTION

We tested the turbulence of the flow coming out of the contraction cone when a screen is placed at the entrance of the test section, rendering the flow in the test section highly turbulent. This has been done by passing a hot wire holder through the meshes of the grid, and placing the wire about 2" upstream of the grid. Under such circumstances, the turbulence of the incoming flow is slightly larger, as indicated by the small triangles on Fig. 11. We observed with this arrangement that the incoming turbulence has a small lateral correlation, and that the longitudinal size of the eddies is about 2" at 8 m/sec.

Conclusions.

The tunnel has been used over several months and experiments on isotropic turbulence have been performed. We found that, after a warming time of about 1 hour, the tunnel was steady and that speed and temperature remained constant. The noise from the tunnel is very low and no vibrations interfered with the measurements.

The rather narrow and long test section is ideal for the investigations on Lagrangian correlations, that is, for correlations from the point of view of an observer travelling with the flow.

The low noise represents favorable conditions for the study of turbulent pressure fluctuations. This aspect of turbulence is still unexplored for lack of a convenient microphone, and the tunnel could be used either for the design of a suitable microphone or for measurements of pressure fluctuations.

The effect of a contraction on turbulence could be studied in the contraction cone. Similarly, experiments could be carried in diffuser I, especially on the effects of pressure gradients on turbulence.

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